REVIEWS

The Ore Deposits of New Mexico. By WALDEMAR LINDGREN, LOUIS C. GRATON, AND CHARLES H. GORDON. Professional Paper 68, U.S. Geological Survey, 1910. Pp. 361.

This paper treats a subject about which most geologists have known comparatively little, and of which most of us are eager to learn. Although some of the mining districts were worked by the Spaniards long before the United States became a mining nation, the geology and ore deposits of the state are less well known, perhaps, than those of any other portion of the country. During the past decade several papers treating the deposits of large areas have appeared, and these, the reviewer believes, have contributed fully as much to the science of economic geology as the more intensive studies of small areas. The reconnaissance method of study and treatment gives a perspective which detailed work of small and more or less isolated mining districts could never do. This paper is the most comprehensive and in its scientific aspects should be the most useful of its class. The deposits are so varied and their genesis so clearly discussed that the student of ore deposits will find the paper to possess the essentials of a textbook of mining geology.

Pre-Cambrian rocks do not occupy large areas in New Mexico; the largest masses are found in the north and constitute the southern extension of the Sangre de Cristo Range of Colorado. This belt ends some 20 miles south of Santa Fé. Several other, smaller areas of pre-Cambrian rocks are described. The pre-Cambrian rocks consist of quartzites, mica schists of clastic origin, and some limestones. These are intruded by normal granite, which in turn has been intruded by masses and dikes of dioritic rocks. The latter are at some places cut by pegmatite dikes and by a later granite. Schistosity in varying degrees has been produced in both the sedimentary and the igneous rocks. At some places the granite breaks through or contains remnants of older greenstone tuffs, amphiboles, and rhyolites. The pre-Cambrian sedimentaries probably correspond in age to those imbedded in red granite in various places in Colorado. Perhaps they should be correlated also with the quartzitic Pinal schists of southeastern Arizona.

The pre-Cambrian history, one of sedimentation, mountain building, and igneous intrusion, was followed by long-continued erosion,

which exposed the ancient cores. At the base of the Paleozoic is pronounced unconformity. During Cambrian times a land mass probably occupied the northern portion of the state. South of this, fossiliferous Cambrian beds rest upon the ancient complex. The sea shore moved northward during the Paleozoic, and the Ordovician, Silurian, and Carboniferous beds overlap the Cambrian, and extend farther north. In the northern part of the state the Upper Carboniferous rests directly upon the pre-Cambrian, and these conditions continue as far south as Socorro. The Cambrian consists of quartzite, shales, and limestones; the Ordovician is predominantly of limestone; the Silurian of limestone and quartzite.

The fossiliferous Devonian, represented in the western part of the state, is a thin formation of clay shale, calcareous in the upper portion. At some places it is believed there is an unconformity of erosion between the Ordovician limestone and the Devonian, but at many places they are conformable.

The Mississippian is recognized at several places south of latitude 34°. The Pennsylvanian is deposited with considerable thickness over the whole state, reaching a maximum between Santa Fé and Las Vegas. As far south as Socorro, it consists of sandstone and shales in repeated alternation with limestone beds. Farther south the pure limestone prevails and the total thickness appears to diminish. All indicates near shore conditions in the northern part of the state. The upper Carboniferous is divisible into two groups, the upper one of which is of the Carboniferous "Red Beds." Unconformities of erosion mark both the top and bottom of the group. Triassic "Red Beds" are unknown in the southern part of the state, but have been described in the Sierra Nacimiento.

The Cretaceous rests upon the eroded "Red Beds," the Carboniferous, and the pre-Cambrian. This series consists of pliable shales which once extended over the whole territory with greater continuity than any other formation except perhaps the Early Pennsylvanian.

The Tertiary was marked by igneous activity, mountain making and ore deposition. First, manganitic magmas were thrust out as laccolithic masses beneath the pliable, tough Cretaceous sediments. Marine conditions ceased. Lake basins developed, at least in northern New Mexico. Mountain building accompanied and succeeded intrusion. These forces were active mainly in the belt extending southwestward—the extension of the Rocky Mountain region. The pre-Cambrian core to the north was forced up by faulting or by warping and faulting.

Southward the sediments were broken into faulted monoclines—the typical Great Basin structure. Erosion was active in shaping the mountain ranges, especially in the southwest. A second epoch of igneous activity, distinctly separate from the earlier epochs of intrusion, began, probably in Middle Tertiary, as in Nevada, Colorado, Utah, and in general throughout the central West, and andesites and rhyolites, in places 2,000 feet thick, were extravasated upon beveled sedimentaries. A large Miocene lake covered the upper Rio Grande Valley, in part at least. In this, the Santa Fé marl was deposited. Near the close of the Tertiary, basalts covered this marl, and the eroded older sediments and igneous rocks.

These eruptions continued during Quaternary times. In early Quaternary, land deposits of coarse gravels filled some of the structural troughs to a depth of 1,000 feet. Basalt was poured over these gravels and smaller flows, perhaps only a few hundred years ago, were extravasated at several places.

The highly acidic potash-rich granites, products of the pre-Cambrian igneous period, differ greatly from the Tertiary monzonites, quartz monzonites and their lava equivalents, and it is concluded that these two series could not have been derived from a common magma. It is suggested, however, that the Tertiary rocks were derived from the same source and that toward the last a differentiation took place in a magma basin the products of which were basalts and rhyolites.

The mines of the state, it is estimated, have produced some 35,000,000 ounces silver, and $30,000,000 gold, besides considerable lead, copper, and zinc. Like the area of maximum of orogenic activity, fissuring and igneous intrusion, the deposits extend southwestward, through the state, forming a broad belt about 450 miles long, in which eighty-one mining districts or camps are located. Many types of deposits are represented, among them copper and iron ores in sedimentary beds, fissure veins, mineralized shear zones, lenticular veins in gneiss, replacement veins in limestone, irregular replacement deposits in limestone, contact metamorphic deposits and gold placers. At least three epochs of mineralization are represented: (1) Pre-Cambrian, (2) Early Tertiary, (3) Middle and Late Tertiary. There are also, in the "Red Beds" (Carboniferous and later), deposits which are not related to igneous activities and which were formed presumably by cold solutions, in post-Carboniferous times.

The pre-Cambrian deposits are represented in ten districts. Three types have been recognized, quartz-filled fissures, usually of the lenticu-

lar type; shear zones filled with quartz stringers; disseminations of sulphides in amphibole schists. They are in greenstone, granite, gneiss, or amphibolite. Some of these deposits are accompanied by sericitization and the development of horny silicates in the wall rock. Some have been subjected to the stresses of dynamic metamorphism and show the effect of pressure in lenticular development of quartz and in the development of minerals like biotite. The values are gold, silver, and copper. Minerals represented in these deposits are quartz, calcite, siderite, flourite, tourmaline, biotite, epidote, garnet, chlorite, specularite, pyrite, pyrrhotite, chalcopyrite, galena, zinc blend, molybdenite, tetrahedrite, bornite, and chalcocite. It is suggested that these ores are genetically related to the granite magma. The pre-Cambrian deposits are not extensively developed.

Contact metamorphic deposits are developed where the early Tertiary intrusives, consisting of monzonites, quartz monzonite, granodiorites or their porphyries, cut through limestone or calcareous shale. Metamorphism is not excessive and rarely extends more than a few hundred feet in a horizontal distance. Mineralization usually accompanies metamorphism. Copper, as chalcopyrite, is most common in the contact metamorphic deposits, but is usually accompanied by zinc blend. Magnetite is locally developed. With two exceptions, gold and silver are present as traces only. Galena is generally subordinate; pyrrhotite is not common. Other minerals are quartz, calcite, garnet, epidote, wollastonite, tremolite, specularite, magnetite, pyrite, molybdenite. Some of these deposits are important. Indicating a transition between contact metamorphic deposits and fissure veins formed by magmatic solutions under conditions of less temperature and pressure, there are fissure veins in limestone, the walls of which are in part converted to garnet and other heavy silicates. The magmatic solutions causing contact metamorphism added silica and the metals to the rocks intruded.

Certain veins, not replacements in limestone, are in close genetic relation to the same early Tertiary intermediate porphyries, which locally produced contact metamorphic mineralization. Perhaps $20,000,000 gold has been derived from these veins, which are believed to be of deep-seated origin. In a few of these veins silver is the most important metal. Quartz, pyrite, and gold are almost always present; barite is exceptional. Tourmaline, specularite, pyrrhotite, magnetite, flourite, molybdenite, have been noted. Other minerals are calcite, dolomite, chalcopyrite, galena, zinc blend. Wall-rock alterations are

sericitization, carbonatization, silicification, and pyritization; hydrothermal alterations are less extensive than near the vein deposits of the Middle Tertiary age. At Sylvanite, orthoclase (not adularia) is found in small veins more or less closely related to pegmatites, but which are notwithstanding far from the normal pegmatite.

The Santa Rita (Chino) and Burro Mountain deposits also were probably formed in the first concentration at the time of the intrusion of the early Tertiary porphyries. These disseminated copper ores are greatly concentrated by oxidizing surface waters and resemble in many respects the "copper porphyries" of Arizona, Utah, and Nevada.

Replacement deposits in limestone, not contact metamorphic deposits, form an important group which is likewise in close genetic relation to the early Tertiary intrusions. At Lake Valley the eroded ore deposits are covered by andesite. Strongly indicating deposition by ascending magmatic solutions, these deposits have been found in eight of the districts below beds of shale. In six other districts they are fissure veins. Silver is generally the most important metal; lead is almost always present; gold is absent, barite is rare.

The gangue is siliceous, with one or more carbonates. Other minerals are fluorite, wulfenite, vanadite, zinc blend, pyrite, chalcopyrite, argentite, cerargyrite, silver, limonite, and pyrolusite. No heavy silicates are found in the limestone along these veins, but silica or jasperoid has been developed.

Veins of gold and silver ores connected with volcanic rocks of Middle Tertiary or later age are developed in ten mining districts. They are contained in rhyolites, its tuffs and breccias, or in andesites, which have latitic transitions. Some of these deposits are older than early Quaternary basalts. Base metals and sulphides are not prominent in these veins, lead and zinc are rare, though copper is present in considerable amounts in several districts. The gangue is quartz, which may be accompanied by calcite, fluorite, and barite. Adularia is present in two districts. Pyrite and chalcopyrite are common; bornite is probably primary. Other minerals are zinc blend, galena, chalcocite, telluride, tetrahedrite, cerargyrite, etc. Hydrothermal alteration is widespread. These veins are believed to have been deposited by hot waters very near the present surface at the time of deposition. Possibly the waters, such as those which have been analyzed from hot springs at Ojo Caliente, are solutions of the same genesis and character. The discussion of the relation of the deposits to waters of this character is an exceedingly suggestive and valuable section of the paper.

There are certain lead and copper veins of doubtful affiliation which do not appear to belong to any of the groups described and which seem to have no genetic relation to igneous rocks. They are, so far as developed, of small importance.

The copper deposits in sandstone, which, in part at least, replace carbonaceous material and which appear to have no direct connection with igneous rocks, form a relatively unimportant, but an exceedingly interesting group. These ores are mainly in the "Red Beds." The minerals are chalcocite, bornite, chalcopyrite, pyrite, malachite, azurite, silica, barite, and gypsum. Frequently these deposits replace coal. Some ores carry a few ounces of silver to the ton of chalcocite.

It is believed that the metals known to have been present in pre-Cambrian areas were leached out of these as sulphates, and redeposited in sediments that collected in inland lakes or seas. In part they were deposited as the solid detrital sulphides. When surface waters leached such beds, copper was dissolved. The waters of the Red Beds are known to be rich in chlorides and sulphates. From the organic matter in the beds, hydrogen sulphide would be added, and this would readily precipitate copper sulphide.

Pages 82 to 348 contain detailed descriptions of the many mining districts.

W. H. E.

Syllabus of a Course of Lectures on Economic Geology. By JOHN C. BRANNER. Published by Stanford University. 3d ed., 1911. Pp. 503.

This syllabus is intended for the use of students in college and afterward. The method of treatment of the various subjects is mainly by outlines, which are to be expanded by notes from lectures, readings, and observation, and written out on blank pages opposite the outlines. Numerous text figures and cross-sections of mines add greatly to the value of the book. The references are full, well chosen, and up to date.

W. H. E.

Descriptive Mineralogy, with Especial Reference to the Occurrences and Uses of Minerals. By EDWARD HENRY KRAUS. Ann Arbor, Mich.: George Wahr, 1910.

The book contains 334 pages of text and about the same number of blank pages for students' notes. It is designed primarily for the student of general mineralogy, with little reference to microscopical optics.